energy absorption may be so great that what may be a safe exposure level for one person will be dangerous for others.

Of course, this line of thinking is not difficult to follow. The physical characteristics of a small head make the small head more prone to higher levels of energy absorption than a larger head. We've already considered the research that found "hot spot" absorptions due to smaller head size. Also, the shape of the skull, thickness of subcutaneous fat, muscle layering, and how an individual holds a portable cellular telephone each contribute to make the energy absorption different from one individual to another. The important common factor, however, is that all individuals will absorb a large portion of the radiation.

Guy tells us that

> ***For a more exact SAR analysis, one should take into account the bone, the subcutaneous fat, and the complex inner geometry of the body. This would require the development of much more sophisticated models.***[170]

Given this statement, one must wonder how it is that some researchers, using simplified models, have made such bold claims of safety.

A controversy seems to have developed and some researchers are questioning the accuracy of results obtained by using the most simplistic models. Those researchers have confirmed that the simplified spheroidal models are inadequate for considering real power absorption in humans:

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[170] A. W. Guy, "Dosimetry Associated with Exposure to Non-Ionizing Radiation: Very Low Frequency to Microwaves," Radio Physics 53 no. 6 (December I987):569—84.

It appears doubtful, however, that any useful theoretical or numerical solutions can be economically obtained for figure shapes as complex as man.[171]

K. Foster, R. Kritikos, and Schwan also determined from their research that radiofrequency irradiation of simulated biomaterials is not likely to provide accurate estimates of radiation induced temperature distribution in actual tissue.[172] Simplified structures seriously understate energy absorption and temperature rise.

Some reasons for the shortcomings are readily evident. If, for example, a researcher employs a head structure comprised of some single material (saline solution or some gel material), the results cannot reflect the important contributions of nonuniformities and dissimilar layers of an actual human head and brain which are known to dramatically affect absorption. Researchers have learned that as the complexity of laboratory models improves toward more accurate representations of the human head, the experimental results also yield increased absorption findings.

Their belief that useful data could not be economically obtained was destined to be proven wrong. In fact, even the six-layered models in use at that time were providing useful results of real power absorption. Of course, the MRI-based analytic tools developed during the 1990s are superior.

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[171] *A. W. Guy, et al., "Determination of Power Absorption in Man Exposed to High Frequency Electromagnetic Fields by Thermographic Measurements on Scale Models," IEEE Transactions on Biomedical Engineering BME-23, no. 5 (September 1976):361.*
[172] *K. R. Foster, et al., "Effect of Surface Cooling and Blood Flow on the Microwave Heating of Tissue," IEEE Transactions on Biomedical Engineering BME—25, no. 3 (May 1978):313-16.*

Surprisingly, the same group of researchers who were so outspoken about the use of simplified models have reported that their own research, sponsored by the U.S. Air Force, employed those very same types of scaled homogeneous models. Not only were the models scaled down to about one-tenth the size of a human, but also the researchers made the models out of that same "one type fits all" mixture that they say represents the combined properties of all of the different human tissue types. This combination yields a "tissue" that has none of the properties of any human tissues. The researchers call it "2/3 muscle tissue." Nevertheless, from this "tissue cocktail" they have constructed the scaled-down doll-like structures that they used for their "scientific" experiments.

As if the nonrepresentative structure were not enough to violate the standards of good laboratory practices, the researchers also used thermographic measuring techniques to detect energy absorption. Their comments of the technique state that "the heat loss during the several minutes needed for the measurements was negligible."[179]

Other researchers have reported earlier that they were concerned with the validity of measurements that took several seconds; but these researchers were unconcerned with thermographic measurements that took several minutes. We have already discussed that thermal measurements that take long periods of time, that is, several seconds, tend to blur the temperature distinctions in tissue and completely mask thermal "hot spots." A

[179] *A. W. Guy, et al., "Average SAR and SAR Distributions in Man Exposed to 450-MHz Radiofrequency Radiation," IEEE Transactions on Microwave Theory and Techniques MTT—32, no. 8 (August 1984):752-63.*

measurement that takes several minutes no doubt compounds the errors and would provide little, if any, valid information.

On the basis of those toy models of human shapes, made out of a single substance that does not resemble any biological tissue and using poor thermographic methods, those researchers declared that their experimental findings prove exposure to 1 mW/cm² radiofrequency radiation is safe. The models and methods gave absolutely no indications of energy absorptions within any part of any human structure; no measurements within head models; no measurements within human torso models; no computer calculations; only radiation of little dolls. A whole body of literature is available to contradict those simplistic findings. Yet, the researchers have not referred to that published data.

Since the industry identifies the market for their products to be in the region of $100 billion it should be reasonable to expect that funding be made available to construct the more representative models. It's not as if the capability did not exist. It's just that researchers have not been funded to do the work.
Guy underscores this need by writing that

> ***since it is impossible to do many biological effect studies on man, the development of safe human exposure standards must be based on animal experimentation. (see footnote 173).***

The cellular telephone industry has taken this a step further. Rather than provide the realistic models for the researchers, industry has elected to use the public for its experiments. Others reconfirmed what Guy reported.
They stated in 1987 that

among the remaining areas where more work is still needed in RF dosimetry research is the quantification of the near-field absorption by biological models. It is generally feared that the near field may possibly contribute to excessively hazardous absorption conditions.[174]

Perhaps this scientist has been remiss in keeping up with the research literature, but the prospect of near-zone absorption hazards has been proposed, quantified, confirmed, and reconfirmed. There is no maybe about it: "hot spots" dominate the concerns when the human head is exposed in the near-zone of radiating antennas.

Usually the purpose of computer analysis is to verify the experimental results obtained by others or to evaluate new techniques that others have proposed. However, these researchers employ the "tissue cocktail" material characteristics that have become all too familiar by now and which admittedly resemble no known biological tissue. In spite of this, they have performed analyses with the nonexistent material parameters in a computer model (see footnote 174). It would have been just as easy to enter accurate human tissue values, in which case the results would have some basis in reality instead of being related to a nonexistent being.

Other researchers have published depictions of SAR distributions, taken from a compu***174***ter analysis of the human head, that show that for a frontally impinging plane-wave distinct energy absorption "hot spots" are formed

[174] *M. F. Iskander, et al., "Near-Field Absorption Characteristics of Biological Models in the Resonance Frequency Range," IEEE Transactions on Microwave Theory and Techniques MTT—35, no. 8 (August 1987):776-80.*

within the brain.[175] This is interesting since it confirms that even plane-wave induced radiation absorption results in interior energy absorption "hot spots." In this instance the observed "hot spots" amount to an energy absorption (SAR) of 0.6 mW/g for an incident power density of 1 mW/cm^2. In the near-field, that same incident power density would result in a much higher SAR due to a number of enhancement factors, including the nearzone "matching" effect.

8

P. W. Barber, et al., also used a six-layer model in their analyses to arrive at findings that confirmed the earlier work of Joines and Spiegel. That is, a 30 percent increase in radiation absorption results for complex six-layered models rather than the simpler homogeneous and inhomogeneous models previously employed[176] Interestingly, for this study, the greatest peak of the enhancement effect, which the researchers call layering resonance, occurs at about 1,900 MHz—the frequency range of the PCS portables.

The researchers have found that constructing models with representative layers of skin, fat, bone, etc., leads to the "matching" effect, which actually helps the radiofrequency radiation penetrate the head structure most

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[175] *D. T. Borup and O. P. Gandhi, "Calculation of High-Resolution SAR Distributions in Biological Bodies Using the FFT Algorithm and Conjugate Gradient Method," IEEE Transactions on Microwave Theory and Techniques MTT—33, no. 5 (May 1985):417-19.*

[176] *P. W. Barber, et al., "Electromagnetic Absorption in a Multilayered Model of Man," IEEE Transactions on Biomedical Engineering BME-26, no. 7 (July 1979):400-405.*

readily. We've discussed the research findings of "matching" effects earlier, and Barber has reconfirmed the effect. Since the thicknesses of these layers vary from person to person we should also expect that the exact frequency of maximum "enhancement" will vary from one person to another.

In another report, which comes from the same research lab, the researchers replicated the earlier work of Joines and Spiegel to detail a more than twofold increase (108 percent) in average SAR in a layered model over that of a homogeneous model at exposure to 1,200 MHz radiation.177 As would be expected, their data show findings of about the same increase (92 percent) at 900 MHz. Reverification of the earlier published findings confirms the need to distinguish experimental results according to the complexity of the models used. Simplified models underestimate the energy absorption by about a factor of 2 compared to a three—layer model. Earlier researchers I have reported that the energy absorption, when using a six-layered model, is higher yet by a factor of 2 to 3 times.

9

T. Kobayashi has warned that typical gel-type materials are prone178 to dehydration, deterioration and invasion by molds and bacteria. All of these effects lead to inaccurate experimental data, yet nearly all researchers who experiment with laboratory models use the gel mixtures.

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177 H. Massoudi, et al., "Electromagnetic Absorption in Multilayered Cylindrical Models of Man," IEEE Transactions on Microwave Theory and Techniques MTT-27, no. 10 (October 1979):825-30.
178 T. Kobayashi, et al., "Dry Phantom Composed of Ceramics andIts Application to SAR Estimation," IEEE Transactions on Microwave Theory and Techniques MTT-41, no. 1 (January 1993):136-40.

He has found, and other independent researchers have verified his findings, that the gelatinous concoctions do not faithfully duplicate the electrical properties of living human tissues over any period of time. For example, a mixture may be prepared for experimental study and only a few hours later the properties of that material will have changed. Most experiments are conducted over a period of several days or weeks. In those instances the properties of the material are continuously changing during the entire course of experimentation.

Aside from his observations about the gelatin mixtures, Kobayashi provides a number of thermographic images that clearly, and dramatically, depict that radio-frequency energy is absorbed in the head substantially at the location nearest the placement of the antenna. For his experiments he has employed a mixture of dry substances. While this is still far from representing a living human head and brain, at least the electrical properties are not shifting all over creation during the data gathering process.

His findings show that even at an antenna distance of 5 cm, which is a relatively large distance by today's portable telephone designs, the energy absorption maximum is about 1 mW/g. At a more typical antenna to head spacing of 2 cm, as would be the case with some of the "flip-phone" style telephones, the energy absorption is about 3 mW/g. That's far above the safe exposure limit of the IEEE/ANSI standard, but once again, the standard exempts the phones from compliance. Again, keep in mind that this laboratory model is homogeneous —having been constructed with the new "recipe" of materials that these researchers have developed.

A series of experiments, which were designed to quantify the SAR Within a human head model, was performed with a rather interesting structure.179 Although the radiation-generating devices were portable transmitter radios and not portable cellular telephones, valuable energy absorption data would be expected. The interesting part of the experiment comes from a close inspection of the human head model.

In order to construct the model the researchers chose not to use an available human skull but, rather, fabricate a model from synthetic materials. They have provided data that show that the electric fields within the "synthetic skull" are much different from those within the human skull. But they performed the experiments with the "synthetic skull" only.

Continuing, they filled the "synthetic skull" with synthetic brain material and also included a "synthetic eye," but they acknowledge some significant variation in the material properties of the eye compared to what it should have been. This then provided an assembly comprised of a nonrepresentative synthetic skull, filled with homogeneous, featureless, synthetic brain matter, and a nonrepresentative synthetic eye. One might expect that they would begin radiation experiments at that point, but instead they did something that seems at least peculiar, if not suspect.

They added large masses of "simulated muscle tissue" to strategic areas on the surface of the "synthetic

179 R. F. Cleveland and T. W. Athey, "Specific Absorption Rate (SAR) in Models of the Human Head Exposed to Hand·Held UHF Portable Radios," Bioelectromagnetics 10, no. 2 (1989):173-86.

skull." At the forehead of the model they placed a layer of muscle material that is approximately 1/2 inch, or about 1.25 cm, thick. A rather large nose is formed entirely of muscle material. Each eye is completely surrounded by a circular area of muscle material, which appears to be about 3/4 inch thick. At the lower jaw areas, on each side, they have added areas of muscle tissue approximately 1 inch thick. Also, along each side of the "synthetic skull" they have added layers of muscle tissue approximately 1/2 inch thick. Finally, at the particularly susceptible region of the temporal area that has been identified by other researchers as a "hot spot" absorption area, these researchers have added a second, additional, layer of muscle material.

Now, starting with that preposterous model of a human head, which more closely resembles Mr. Bill, a claymation character from a popular television show, they performed a series of radiation exposure experiments and measured the electric field intensity within the simulated brain matter, which was itself inside the "synthetic skull."

We should keep in mind at all times that the measurements were taken at regions that were effectively shielded by the thick layers of muscle material. The significance of this human head model configuration lies in the fact that any energy radiated to the model would first be partially absorbed in the exterior coating of nonrepresentative muscle material before any of the remainder could be transmitted through the skull and into the brain material.

The experimental data show that energy absorption (SAR) within the simulated brain material, at what would be the temporal lobe of the brain, is about 2.3 mW/

g for a radio or telephone radiating 0.6 watts. For operation with the antenna in front of the face the experimental results show that as much as 2.2 mW/g will be deposited in the eye.

Now, we should recollect that earlier researchers have repeatedly determined multilayered structures (models) comprised of skin, fat, bone, dura, CSF (cerebro-spinal fluid), and brain layers provide a much higher level of absorbed energy than simplified "brain-stuff-in- skull" models. The reason is that the layers can interact to enhance the radiation absorption in a way that makes the layers covering the brain appear to be substantially invisible to the radiation. Not only have these researchers excluded the multilayering details of a proper model, but they have also compounded the error by covering the model with a layer of energy—absorbing musclelike material. This is about as realistic as placing a window shade over the outside of a window and then measuring how much visible light is passing through to the inside of the room.

But, at the same time we should not lose sight of the impact of this research . The findings of greater than 2.0 mW/g of radiofrequency energy absorption within the brain are dramatic. The ANSI safety standards limit exposure to 1.6 mW/g. If the ANSI standards were to apply to portable hand-held transceivers this would be a clear violation of the maximum exposure limits, but existing portables are not regulated.

In addition, one of the reasons for the concept of the exclusion clause in the ANSI standard is that industry researchers argued that radiation from hand-held transmitters is not absorbed into the brain. Their reasoning stated a "peculiar nature" of the electric and magnetic fields but never described that peculiarity in physical or any other scientific terms. In direct contradiction of those representations, Cleveland and Athey have found deep energy penetration and absorption even with a laboratory model that was constructed to minimize any energy absorption of radiofrequency radiation.